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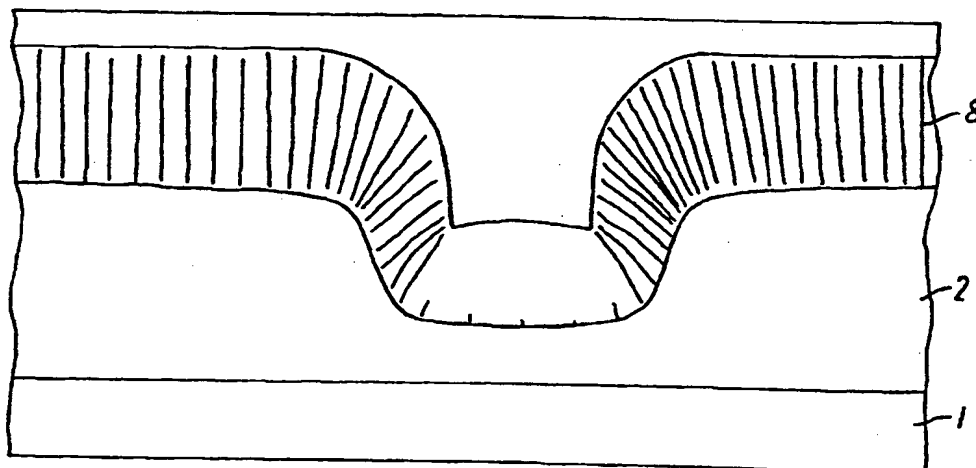
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OPTICAL WAVEGUIDES

(57) Abstract

A structure of integrated optical components made on a plane surface on a substrate. A first glass layer (2; 27) having a plane surface is made, and then a channel (6, 7; 28) is formed in the plane surface of the first glass layer (2; 27). A second glass layer (9; 29) is deposited on the glass surface provided with a channel (6, 7; 28). The channel (6, 7; 28) in the surface of the first glass layer is formed or treated prior to the deposition of the second glass layer (9; 29) in such a way that at least the parts of the channel sides nearest the bottom of the channel converge toward the bottom of the channel. An optical unit having a waveguide structure on a substrate comprises two glass layers (2, 12) which surround at least one waveguide (13) made of glass having a core refractive index which is larger than the cladding refractive index of the glass layers (2, 12). The waveguide (13) has an approximately trapezoidal cross section with two opposed sides which converge toward each other in a direction toward the first deposited cladding layer (2) of the two cladding layers (2, 12).

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A method of making integrated optical waveguides, and an optical unit having integrated optical waveguides.

5 The invention concerns a method of making a structure of integrated optical waveguides on a plane face on a substrate, and is moreover of the type defined in the introductory portion of claim 1. The invention also concerns an optical unit having a waveguide structure as
10 defined in the introductory portion of claim 18.

In optical data communication, information is transferred as light pulses in optical fibres. To process the information in the optical fibres in an efficient manner,
15 efforts are devoted to the development of industrially useful components constructed as integrated optical components, i.e., optical waveguide components and the like made, e.g., in silica, and typically provided on top of a silicon substrate (wafer). Integrated, optical
20 waveguides are relatively large compared with components known from integrated electronics, and therefore not very many components can be accommodated on a substrate wafer. Furthermore, two closely spaced components will interact, which additionally reduces the number of components on a
25 silicon wafer.

Different types of glasses may be used in the fabrication of, e.g., waveguides. These types of glasses may coarsely be divided into two main types, namely soft glass and
30 hard glass. The soft glass is doped with either boron, phosphorous or arsenic (if necessary combinations hereof). When the glass contains these elements, its flow-transition point is lowered, i.e., the temperature

where the glass becomes relatively liquid, and it will then be possible to make the glass flow at relatively low temperatures (1000 - 1100 degrees centigrade). Hard glass is without the above-mentioned dopants and therefore will
5 not begin to flow at these temperatures.

Regardless whether hard or soft glass is involved, the glass may furthermore be doped with one of the rare earths, such as erbium, neodymium or ytterbium, by means
10 of which an active unit may be obtained. As an example erbium is used in the optical fibre amplifiers now frequently used, and lasers may be fabricated in erbium doped fibres as well. The rare earths may thus be used for regeneration of an optical signal, which constantly
15 diminishes during transmission due to optical losses. Erbium is especially interesting since it may amplify the optical signals at the 1550 nanometer wavelength, which is one of the wavelengths most frequently used in telecommunication. Therefore, it will be of interest if
20 erbium doped waveguides could be fabricated.

A typical method of manufacturing optical waveguides is to deposit a relatively thick layer of glass having a low refractive index on the substrate wafer. On top of this a
25 thinner layer of glass having a high refractive index is deposited, and with a suitable masking technique etching is performed in the latest deposited layer, such that an essentially rectangular waveguide profile is produced. The waveguides will hereby lie as scattered mountain
30 ridges on the thick glass layer. The manufacturing procedure gives rise to roughness on the sides of the waveguide, thereby causing losses. To protect the waveguide, a further layer of silica glass having a low

refractive index is deposited on top of the "mountain ridges".

One of the most frequently used methods for deposition of glass is PECVD (Plasma Enhanced Chemical Vapour Deposition). This is particularly so concerning erbium doped waveguides, where PECVD on the whole is the sole method which can ensure a well-ordered incorporation of the erbium ions in the glass matrix as well as in a sufficient amount, such that fabrication of waveguides with a large, homogeneous, erbium concentration is possible.

However, PECVD glass is deposited in a non conformable manner, which means that the structure of the resulting surface after deposition may be considerably different from the starting point. This has some rather unfortunate properties, namely that there will be a tendency towards forming air pockets or voids along the waveguide, and that areas where there is a small distance between two adjacent waveguides (e.g., in a directional coupler or a splitter) tend not to be completely filled, which is detrimental to the properties of the component. These air pockets give rise to losses since the distribution of the optical energy along the waveguide will be considerably affected by these, and the distribution of the optical energy around the waveguide core will be asymmetric, as the air pockets act as optical isolators.

At the same time it will be extraordinary difficult to ensure a plane surface after the latest deposited silica layer, since the waveguides, as mentioned, lie as scattered mountain ridges on the wafer. Even with the

application of a very liquid polymer film, it will be difficult to obtain a plane surface, as the polymer film tends to slide down from the top of the waveguides to a lower level around the waveguides.

5

A method is known, which can rectify the mentioned problems to some extent. After the fabrication of the waveguide cores a thin (approx. 3 μm) layer of boron- and/or phosphorous-doped glass (i.e. soft glass) is deposited, after which the entire structure is given a 12-hour heat treatment at 1100 degrees centigrade in an atmosphere of nitrogen. The just deposited soft glass will then flow and lie neatly around the core. This procedure of depositing a thin layer of soft glass with subsequent heat treatment is repeated two times, after which the structure has such a nature that the thicker glass layer may be deposited without introducing voids or air pockets. The thicker glass layer is then given a heat treatment too. The waveguide core is thus given four heat treatments at 1100 degrees centigrade, each of 12 hours' duration.

This method is, however, difficult and time-consuming, and has the great disadvantage that erbium doped waveguides cannot withstand the high temperatures and the long duration, since it is detrimental to the erbium distribution in the waveguide. At high temperatures the erbium ions begin to diffuse around in the glass matrix. They have a pronounced tendency towards forming clusters, which destroys their otherwise positive influence.

US 4 902 086 describes an optocoupler on a substrate where the actual waveguide is formed. The cores of the

waveguides are rounded by means of heating. This method cannot be used on waveguides formed in hard glass, which has better optical qualities than the soft glass.

5 Waveguides may also be fabricated by first depositing a glass layer having a low refractive index, etching or otherwise forming a channel in this glass layer, and then depositing a glass layer having a higher refractive index (core refractive index) in the channel, which then
10 constitutes the waveguide.

US 5 037 168 shows such an optical waveguide fabricated in an SiON-substrate having etched therein a channel which, before establishing the waveguide, is lined with a
15 polymer smoothing layer which is spun on the substrate.

Using this method, however, one finds the same problems as described above. If the glass layer, which will act as the waveguide, is deposited by PECVD, and this is the
20 sole applicable method regarding erbium doped waveguides, as mentioned, voids will form near the corners of the channel.

The object of the invention is to provide a method of
25 fabricating a structure of integrated optical waveguides on a plane surface on a substrate, by means of which the creation of air pockets or voids may be avoided.

This object is achieved in that the channel in the
30 surface of the first glass layer is formed or, before the deposition of the second glass layer, is treated such that at least the parts of the channel sides nearest the

bottom of the channel converge toward the bottom of the channel.

5 The formation of the closed pockets will hereby be avoided, since the second glass layer will grow on a surface without sharp or vertical edges.

10 In the case where the waveguides are formed as mountain ridges on a glass layer or on the substrate, and where the space between the waveguides thereby constitutes the channel, it will be appropriate that the channel is formed directly with the desired cross-section, e.g. by etching, as stated in claims 3-6. This has the advantage that hard glass can be used for the waveguides, which can likewise
15 be erbium doped since no long heat treatments at high temperatures occur. The fabrication time is furthermore short and thereby reduces the costs. Finally, the resulting surface will be plane, which allows immediate integration of more layers of waveguides.

20 In the case where the waveguide is deposited in a channel made in advance, it may, as stated in claims 7-9, be appropriate that the desired form of the channel is created by a post treatment of the etched channel.

25 The treatment of the edges of the channel may advantageously be performed as stated in claim 10, since a single heat treatment ensures that the edges of the channel are rounded. Since, here, the channel is formed
30 in cladding glass, it will not contain any erbium dopant and can therefore withstand a heat treatment. The rounded edges may advantageously have radii of curvature of the same order of magnitude as the final depth of the

channels, i.e. at least one tenth of this. The radii of curvature are controlled by the temperature and the duration of the heat treatment.

5 If the substrate is composed of a suitable glass material, the first glass layer may be formed by one of the sides of the substrate, but often, as stated in claim 12, a relatively thick buffer layer of glass will be deposited on the substrate. The channels may then be
10 etched in the surface of the buffer layer, after preceding deposition of an etch mask on the surface. The buffer layer ensures minimal coupling between the waveguides and the substrate, which is typically composed of silicon.

15

The second glass layer may e.g. be deposited by means of PECVD (Plasma Enhanced Chemical Vapour Deposition). Plasma deposition is relatively slow, and therefore the deposition may advantageously be stopped just after the
20 channels are completely filled (1-2 μm above), so that the channel pattern is still recognisable through the second layer. The filling must be at least 5 - 8 μm higher before the surface of the second layer may be regarded as being plane.

25

Therefore, a polymer film may advantageously be applied by spin-on, since the very liquid polymer material will fill up the channels without any problems and form a completely plane surface. It is important to use an
30 etching means here which exhibits the same etching rate in both the polymer film and the second glass layer, at any rate when etching in both polymer and glass.

Finally, the etching-away of the second layer may proceed for a period sufficient to remove also the uppermost portion of the first layer. The uppermost and widest layer of the channel will be removed hereby.

5

As stated in claim 17, an extra, relatively thin layer of glass corresponding to the first glass layer may be deposited. The etched surface on the first glass layer will have a roughness owing to the etching which differs from the roughness of the second glass layer. The deposition of this further glass layer before the deposition of the second glass layer causes the roughnesses to be adapted, thereby reducing the optical losses of the waveguide.

15

Since the surface of the first glass layer with filled channels may hereby be made completely plane, also the third glass layer may be made completely plane. The interface between the core and the cladding of the waveguide will simultaneously have a very small roughness. Finally, there will be no air pockets or voids causing losses. Only a small portion of the optical energy will migrate into the cladding, and this portion will be approximately rotationally symmetrical about the central axis of the waveguide. The coupling between two waveguides can hereby be controlled very accurately by controlling the distance between the waveguides.

25

Thus, the third glass layer can form the basis for additional channels for the formation of a new layer of waveguides, and will thus also serve as the first glass layer for the new waveguide layer. It will thus be possible to form a structure having many, parallel

30

waveguide layers. Here, the third layer is to have a thickness of 3-5 times the depth of the channel if optical separation is to be achieved. If optical coupling is desired, the distance between two waveguides must be e.g. 1-5 μm according to the strength of the coupling.

When the first glass layer on the substrate is heated, the edges of the channels tend to become slightly trapezoidal, for which reason, of course, the invention also concerns an optical unit of the type defined in the characterising portion of claim 18.

The invention will be described more fully below in connection with preferred embodiments and with reference to the drawing, in which

fig. 1 shows a drawing of a picture taken with an electron microscope of a cross-section of a substrate with applied glass layers made according to the invention,

figs. 2-19 illustrate various procedures in the making of a waveguide structure according to the invention,

fig. 20 shows an example of voids,

fig. 21 shows a channel according to the invention, and

fig. 22 shows the channel from fig. 21 filled with a glass layer.

Fig. 2 shows a standard silicon wafer 1 which is used as a substrate in the preferred embodiment. A skilled person

will realise that the dimensions are not drawn to scale in the illustrated example, but this has been done for clarity and for facilitating the understanding of the invention.

5

To avoid bubble formation in the glass layers on the silicon substrate, the latter may be oxidised by heating prior to the application of glass, thereby forming silicon dioxide on the surface of the substrate.

10

As shown in fig. 3, a relatively thick layer of glass 2a is deposited on the silicon wafer 1, e.g. by PECVD (Plasma Enhanced Chemical Vapour Deposition). This first glass layer 2a serves as a first glass layer in a buffer (optical separation) between the wafer 1 and the waveguides formed later. The thickness of the glass layer 2a is typically about 15 μm or more. The glass layer 2a may be a phosphorous glass (PSG), a boron glass (BSG) or, like in the preferred embodiment, a combination (BPSG). Another layer 2b of phosphorous and/or boron doped glass is applied on top of the glass layer 2a. The layers 2a and 2b are collectively designated by the reference numeral 2. If the silicon wafer 1 is not oxidised, the glass layer 2a has to be non-doped.

25

As shown in fig. 5, a thin mask layer 3, e.g. polysilicon, is then applied, and this layer forms part of the mask formation in the etching of the channels. As shown in fig. 6, a thin photoresist layer 4 is applied on the mask layer 3 by means of spin-on or a suitable thin film technique. The photoresist is exposed and developed/fixed in a known manner. Areas 5 of the surface

30

of the wafer will hereby be exposed, which is shown in fig. 7.

The subsequent etching with e.g. KOH or RIE ($\text{SF}_6 + \text{O}_2$) causes the mask layer 3 to be removed in the exposed areas 5, which is shown in fig. 8. The photoresist mask 4 is then removed, as appears from fig. 9, while the polysilicon layer 3, to which the pattern of the photoresist mask has been transferred, is maintained. The polysilicon layer is more stable during the subsequent glass etching than the photoresist mask 4.

As appears from fig. 10, trenches or channels 6 are etched below the exposed areas with the polysilicon layer 3 as a mask. The channels 6 have an approximately rectangular cross-section with a height and a width corresponding to the dimensions of the waveguide which is being established. The polysilicon layer 3 is then removed, thus leaving the first glass layer 2 naked, but provided with channels for the formation of the waveguides, which is shown in fig. 11.

When the glass layer 2 is boron and/or phosphorous doped glass (BPSG), heating of it to a temperature of about 900-1100 degrees centigrade for a period of from, e.g., a few hours up to 12 hours, according to the temperature and boron/phosphorous concentration, ensures that the edges of the channels are caused to flow, whereby the sharp top edges or bottom corners of the trench or the channel become soft and rounded. This is shown in fig. 12. The heating is to take place at a temperature which is higher than the flow temperature of the glass, and is to have a duration which is long enough for the edges to

flow. The rounded channels are designated by the reference numeral 7. Phosphorous increases the refractive index, while boron reduces it. Both materials reduce the flow temperature.

5

The radii of curvature of the rounded corners will be considerably larger than the radii of curvature of the channel edges produced by etching alone. Typically the radii of curvature will be of the same order as the depth of the channels, i.e. the ratio of the two parameters will be from 0.1 to 10. Heating is mentioned as being suitable for achieving the soft edges, but other methods may be used, e.g. laser treatment of the edges.

10

The glass layer 2 with rounded channels 7 may then optionally be coated with a quite thin layer of glass corresponding to the first glass layer 2. This layer will have a thickness of below 1 μm and will ensure adaptation of the roughness of the first glass layer to the actual waveguide core. This reduces the optical losses of the waveguide. However, the heating will already have caused considerable smoothing of these roughnesses. The layer may be a low refractive fusion layer, so that the waveguide may be formed with a segmented core, which is known from fibre optics.

20

25

A second glass layer 9 is then applied by PECVD on the extra glass layer or directly on the glass layer 2, which second glass layer is to form the core of the waveguide and therefore has a refractive index which is slightly greater than the refractive index of the cladding, which consists i.a. of the layer 2. The glass layer 9 has a thickness such that the channels 7 are more than

30

completely filled. Since the waveguide is typically rectangular having a cross-section of 6-8 μm , a layer thickness of 7-11 μm is usually suitable. As shown in fig. 13, the channel structure is still visible through
5 the second glass layer 9.

To facilitate the subsequent deposition of the polymer film, the substrate with glass layers may be heated, the result of which is shown in fig. 14. It will be expedient
10 to apply a very liquid polymer film 10 by spin-on, since this, following baking, will cover the surface of the wafer with a completely plane layer. This is done in fig. 15.

15 The core layer 9 may be doped with rare earths, such as Er or Yt, if an active component is to be established. In addition, it may be doped with Al or La, if the efficiency of the component is to be increased. First, an aggressive etch is used for removing the polymer film to
20 a level corresponding to the surface of the core layer 9, see fig. 16.

Then, an etch is selected, having the same etching rate for the polymer film 10 and for the second glass layer 9.
25 A plane surface is hereby maintained during and after etching. This is shown in figs. 17 and 18. It may be expedient to control the etching so that it is interrupted only when, e.g., 0.1 μm of the glass layer 2 has been removed as well. Examples of etch include
30 (optionally RIE) plasma etch.

The polymer film 10 may optionally be omitted, if the glass layer is allowed to grow to, e.g., the double

thickness, as the depressions 11 (see fig. 13) on the upper side of the layer will be less pronounced. Fig. 18 shows a waveguide core 13, the plane surface of the first waveguide layer 2.

5

Fig. 19 shows that a third glass layer 12, which normally corresponds to the first glass layer 2 in terms of material, is deposited on the exposed surface of the glass layer 2. The deposition may take place using PECVD.

10

The result will then be an optical unit, which is shown in fig. 19, where a waveguide 13 is surrounded by two glass layers 2, 12 which serve as a cladding for the waveguide. The glass layer 12 usually has a thickness of 15 10-20 μm if optical isolation is desired, or 1-5 μm if optical coupling is desired, and the process outlined above can then be repeated on the upper side 14 of the glass layer 12, which will then constitute the first 20 glass layer in the repeated procedure. Thus, parallel waveguide layers may be formed as needed, and there will be no problems of undesirable interaction between the individual waveguides.

Fig. 1, which is a drawing of a picture of a structure 25 corresponding to the one in fig. 13 taken with an electron microscope, clearly shows the rounded edges on the glass layer 2, and it will likewise be seen how the finished waveguide 13 (see also fig. 19) will have an approximately trapezoidal cross-section. The two inclined 30 sides converge in a direction toward the substrate 1 or the glass layer 2 deposited first. The intersection of the lines is disposed outside the picture.

Fig. 20 shows an example of how the mentioned air pockets and voids may look like in the situation, where a layer of cladding glass is deposited to cover two closely spaced waveguides. The picture is a drawing of an SEM-picture (Scanning Electron Microscope picture). A structure having typical dimensions for a directional coupler is etched into a silicon substrate 21, followed by a layer of PECVD deposited glass 22 over the etched structure. The waveguides 23 are 6 μm on each side. As is evident from the picture, there are areas 24 next to the sides of the waveguides where the glass has not merged in the deposition process, and which appear as slanted cracks. Such a void gives rise to optical losses, and at the same time makes the glass unstable, since the crack is likely to grow with time. As is evident, a very large void 25 is present between the two waveguides, and a structure like the one shown will never be able to function as intended. The figure is therefore just intended to show the problems regarding PECVD. Furthermore, it should be noted that the resulting surface 26 is far from being plane.

The process is based upon the fabrication of channels, which are subsequently filled. In this context, the volume between two closely spaced waveguides may be considered as a channel which has vertical side walls, as is seen in fig. 20. Such a channel can, as is seen, not be filled. Therefore, it is necessary to shape the channel in such a way that PECVD glass can be deposited in the channel. The problem can be solved with a channel like the one shown in fig. 21. The process is here based upon a channel 28 having slanted side walls, etched into the first glass layer 27, which is subsequently filled.

It has been possible to device an etch process which gives full control over the side wall slope. As is seen in fig. 20, especially the bottom corners give rise to problems, and it is therefore important to control the lower parts of the side walls.

The next step is to fill the channel with glass in such a way that voids do not appear. This is shown in fig. 22, where the channel 28 is perfectly filled with the deposited glass layer 29, without voids. The thick black line 30, which is drawn, indicates the level to where the surplus glass must be removed. The result is a structure with a plane surface, in which one or more channels are present, having a trapezoidal cross-section, as shown. Finally, a layer of glass is deposited on the top, to protect the waveguides.

P a t e n t C l a i m s :

1. A method of making a structure of integrated optical waveguides on a plane face on a substrate, said method comprising:
- forming a first glass layer (2; 27) having a plane glass surface;
 - forming a channel (6, 7; 28) in the plane glass surface on the first glass layer;
 - depositing a second glass layer (9; 29) on the glass surface formed with a channel (6, 7; 28);
- C H A R A C T E R I Z E D in that the channel (6, 7; 28) in the first glass layer surface is formed or, before the deposition of the second glass layer (9; 29), is treated such that at least the parts of the channel sides nearest the bottom of the channel converge toward the bottom of the channel.
2. A method according to claim 1, C H A R A C T E R - I Z E D in that the deposition of the second glass layer (9; 29) is done using PECVD (Plasma Enhanced Chemical Vapour Deposition).
3. A method according to claim 1 or 2, wherein the structure of integrated optical components is composed of at least two closely spaced waveguides (23) of a glass material having a core refractive index surrounded by a glass material having a cladding refractive index, which is lower than the core refractive index, C H A R - A C T E R I Z E D in that

- the first glass layer (27) having a plane glass surface is formed with a core refractive index;
- that the channel (28) in the surface of the first glass layer is formed so that it separates the at least two waveguides, and so that the parts of the channel sides nearest the bottom of the channel converge toward the bottom of the channel; and
- that the second glass layer (29) having a cladding refractive index is deposited on the glass surface with the channel (28).

4. A method according to claim 3, C H A R A C T E R-
I Z E D in that the channel (28) is formed in such a way
that it obtains a trapezoidal cross-section, the sides of
which converge toward the bottom of the channel.

5. A method according to claim 3 or 4, C H A R A C T E R-
I Z E D in that the channel (28) is formed by etching in
the surface of the first glass layer.

6. A method according to claims 3-5, C H A R A C T E R-
I Z E D in that a part of the second glass layer (29) is
removed to a level where the surface will be plane, and
where substantially just glass having a cladding
refractive index will be present in the channel (28)
formed in the first glass layer, and that a third glass
layer having a cladding refractive index is deposited on
top of said plane surface.

7. A method according to claim 1 or 2, wherein the
structure of integrated optical components is formed by
a waveguide (13) of a glass material having a core
refractive index surrounded by a glass material having a

cladding refractive index, which is lower than the core refractive index, C H A R A C T E R I Z E D in that

- the first glass layer (2), having a plane glass surface is formed with a cladding refractive index;
- 5 • that the channel (6, 7) in the surface of the first glass layer is treated in such a way that the parts of the channel sides nearest the bottom of the channel converge toward the bottom of the channel; and
- that the second glass layer (9) having a core
10 refractive index is deposited on the glass surface in which the channel (6, 7) is provided.

8. A method according to claim 7, C H A R A C T E R-
I Z E D in that the channel is treated so that the sides
15 or transitions of the channels to the bottom of the channel extend over curved faces.

9. A method according to claim 7 or 8, C H A R A C-
T E R I Z E D in that the channel is treated so that the
20 sides or transitions of the channels to the plane surface of the first glass layer extend over curved faces.

10. A method according to claims 7-9, C H A R A C T E R-
I Z E D in that, prior to the deposition of the second
25 glass layer (9), the first glass layer (2) provided with a channel (6, 7) is heated to a temperature which is higher than the flow temperature of the first glass layer (2), and that the heating is performed for a period of time which is sufficient to ensure that the edges of the
30 channel (6, 7) flow.

11. A method according to claims 7-10, C H A R A C-

- 5 T E R I Z E D in that a part of the second glass layer (9) is removed to a level having a plane surface, where substantially just glass having a core refractive index will be present in the channel (6, 7) formed in the first glass layer, and that a third glass layer (12) having a cladding refractive index is deposited on top of the first plane surface with the channel (6, 7) filled with glass having a core refractive index.
- 10 12. A method according to claims 7-11, C H A R A C-
T E R I Z E D in that the formation of the plane surface of the first glass layer (2) comprises deposition of a glass layer on the substrate face.
- 15 13. A method according to claims 7-12, C H A R A C-
T E R I Z E D in that the formation of channels (6, 7) in the plane surface of the first glass layer (2) comprises etching of the surface, and that, prior to etching, the first plane surface is provided with a mask (3, 4) which
20 exposes a pattern on the surface so that channels (6, 7) are formed in the exposed areas by the etching.
- 25 14. A method according to claim 7, C H A R A C T E R-
I Z E D in that the second glass layer (9) is provided with a polymer film (10) by spin-on prior to etching.
- 30 15. A method according to claim 14, C H A R A C T E R-
I Z E D in that the etching means used is an etching means which has the same etching rate for the polymer film (10) and the second glass layer (9).
16. A method according to claims 7-15, C H A R A C-

T E R I Z E D in that the etching-away of the second glass layer (9) comprises etching of part of the surface of the first glass layer (2).

5 17. A method according to claims 7-16, C H A R A C -
T E R I Z E D in that an additional layer of glass of the
same material as the first glass layer (2) is deposited
on the first glass layer (2) surface with channels (6, 7)
having rounded edges prior to the formation of the second
10 glass layer, and that the additional layer of glass is
thin with respect to the thickness of the second layer of
glass (9).

15 18. An optical unit having a waveguide structure on a
substrate, said waveguide structure comprising two layers
of glass (2, 12) which surround at least one waveguide
(13) of glass having a core refractive index higher than
the cladding refractive index of the glass layers (2,
12), C H A R A C T E R I Z E D in that the waveguide (13)
20 has an approximately trapezoidal cross-section, and that
the trapezium has two opposed sides which converge toward
each other in a direction toward the first deposited
cladding layer (2) of the two cladding layers (2, 12).

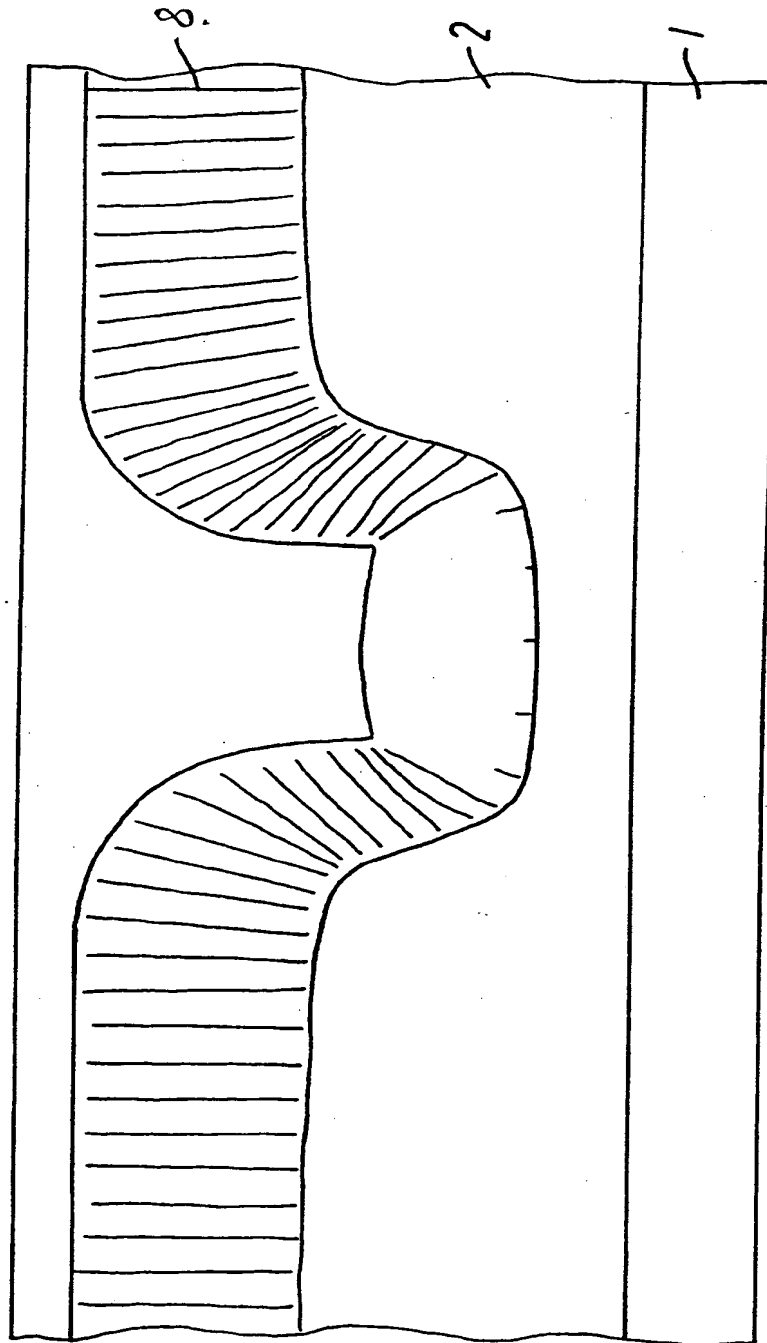


FIG. 1

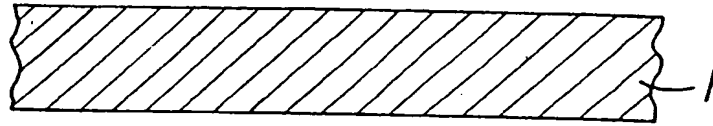


FIG. 2

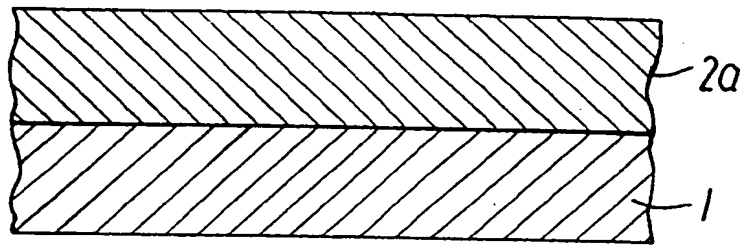


FIG. 3

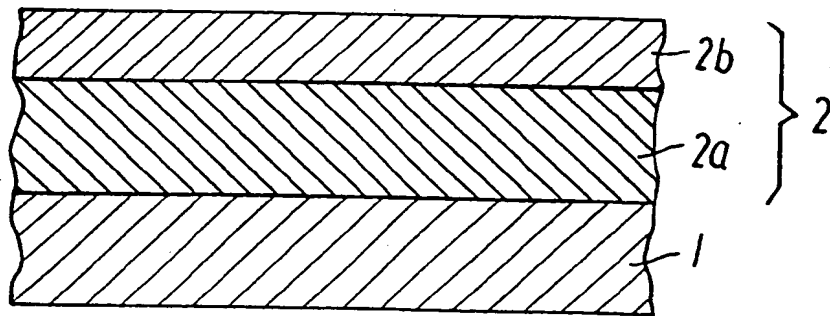


FIG. 4

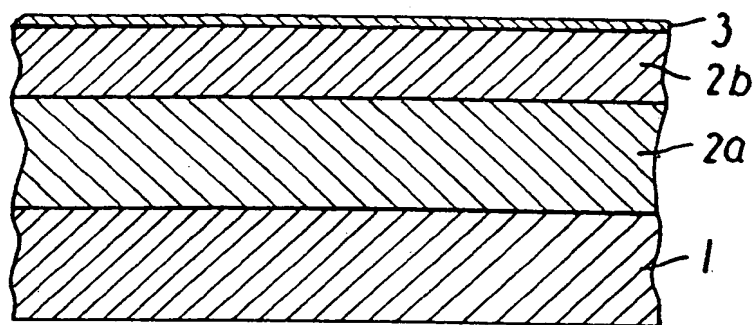


FIG. 5

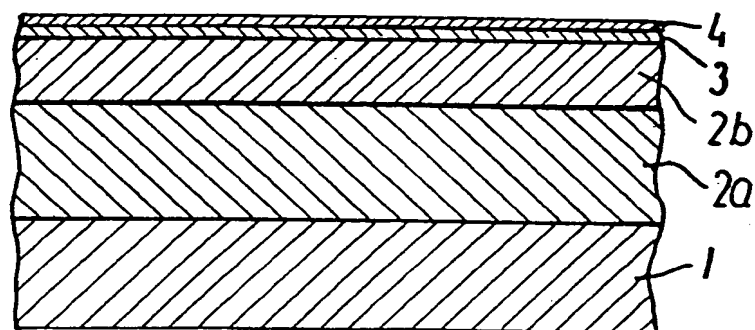


FIG. 6

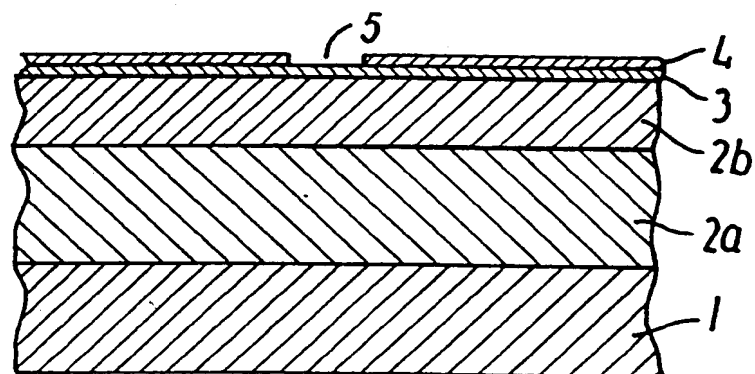


FIG. 7

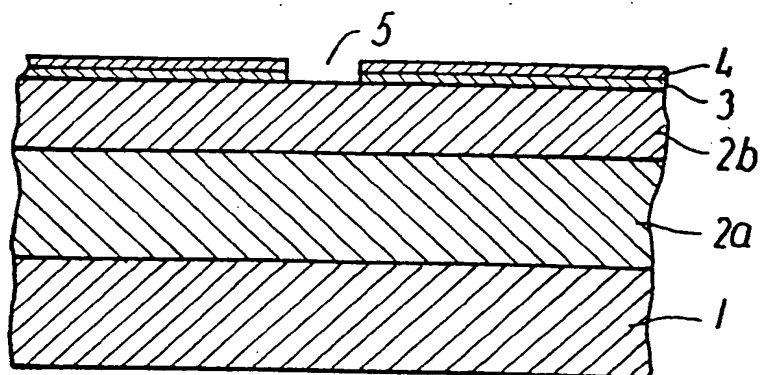


FIG. 8

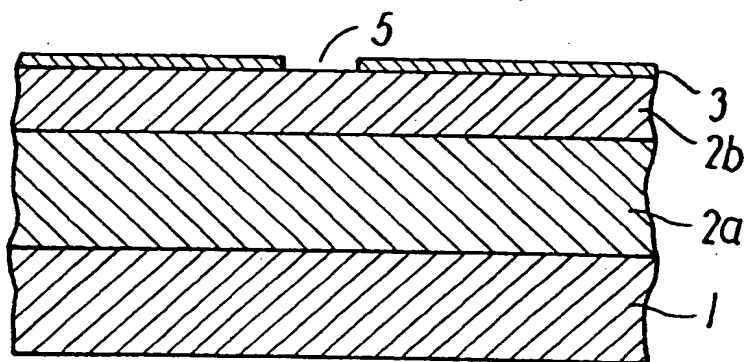


FIG. 9

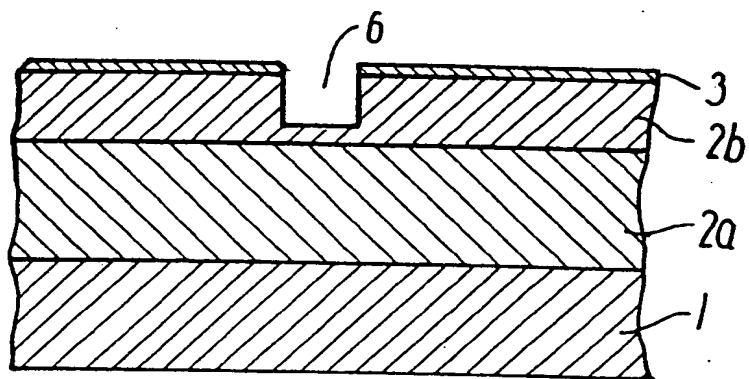


FIG. 10

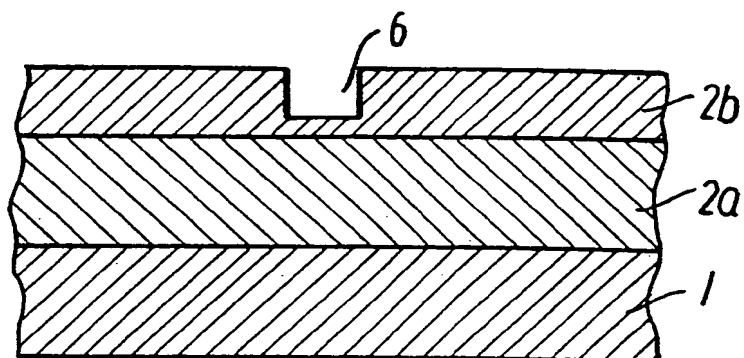


FIG.11

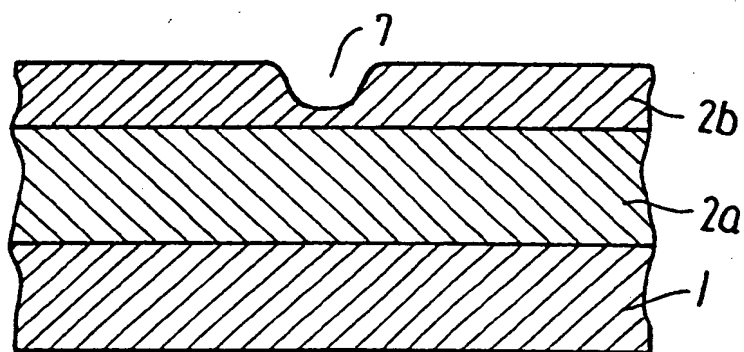


FIG.12

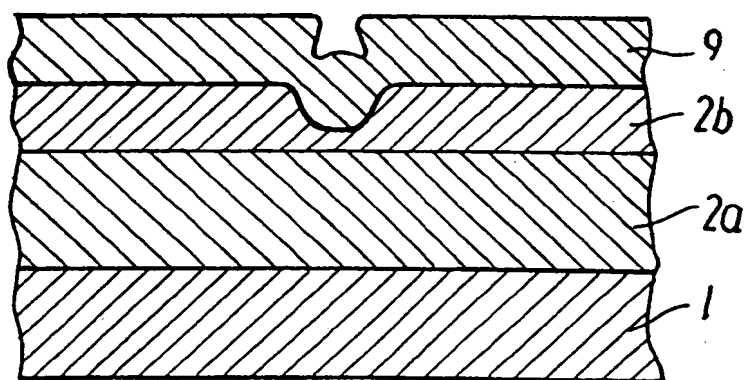


FIG.13

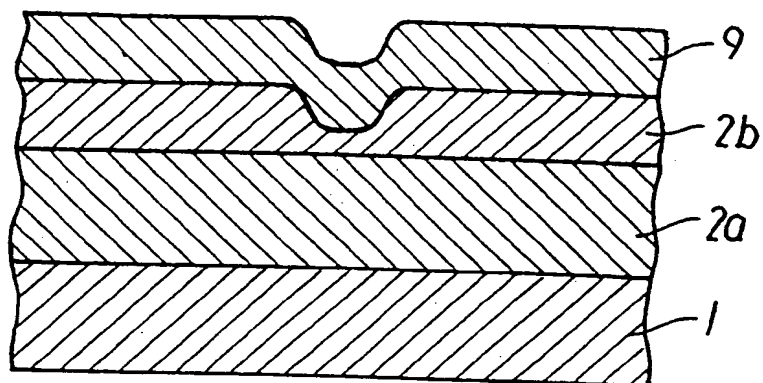


FIG. 14

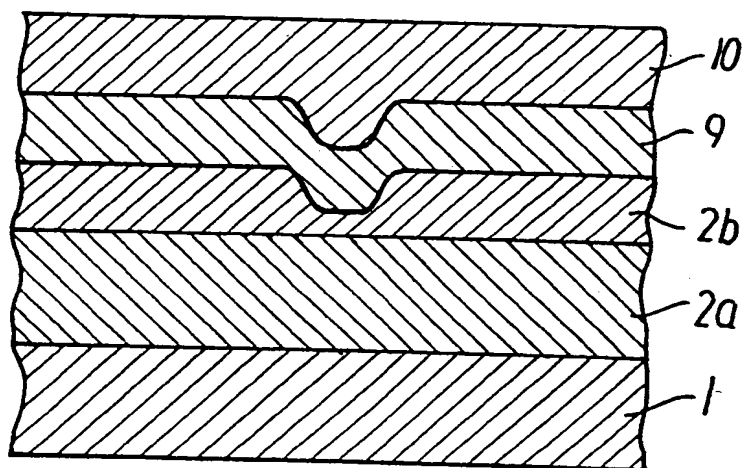


FIG. 15

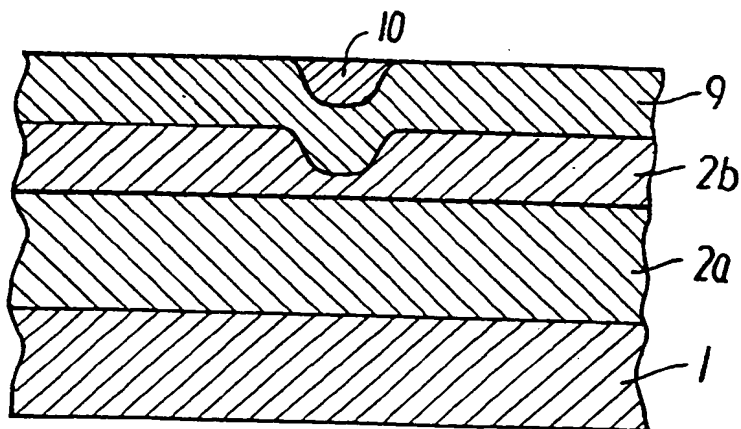


FIG. 16

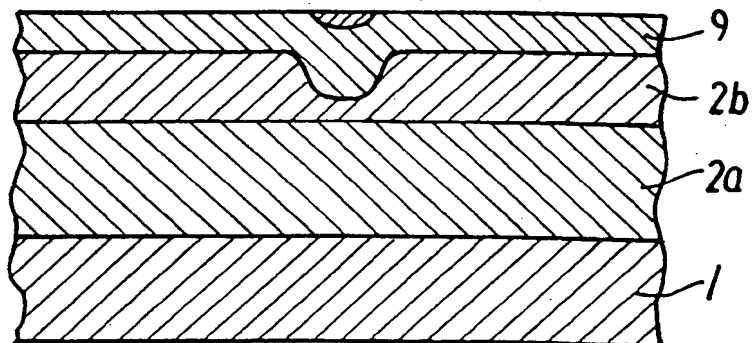


FIG.17

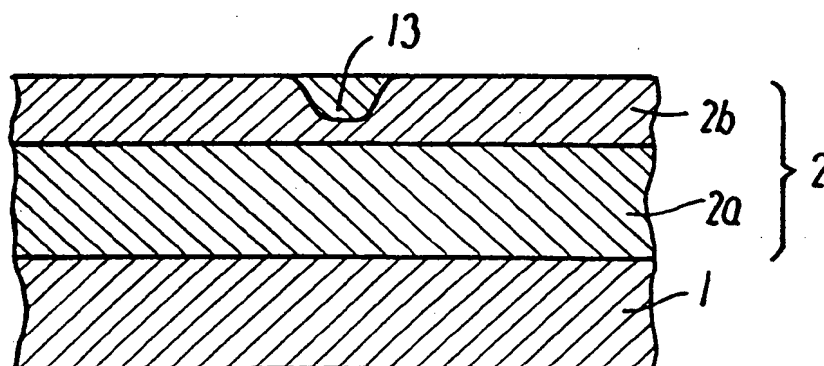


FIG.18

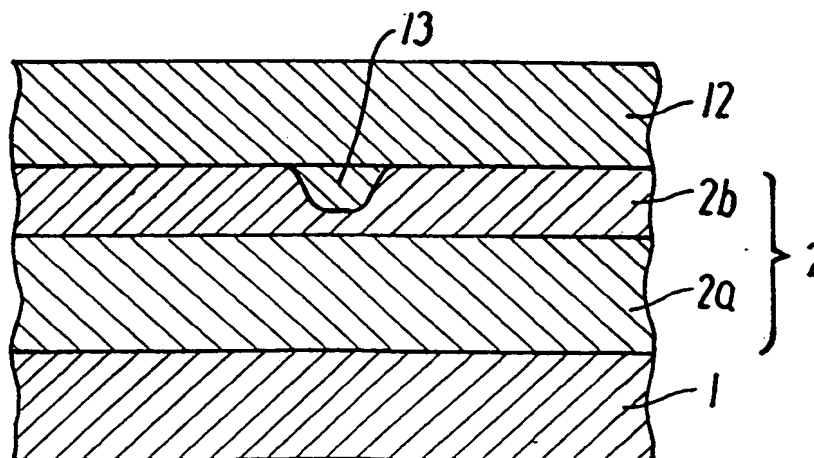


FIG.19

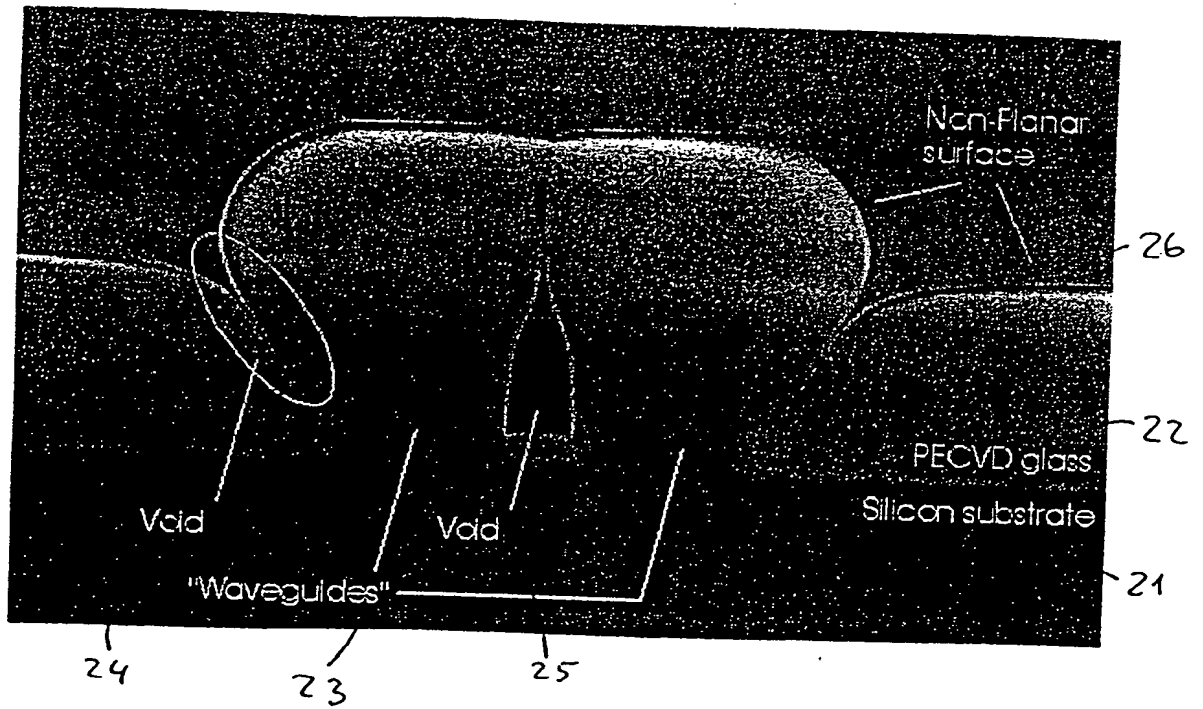


Fig. 20

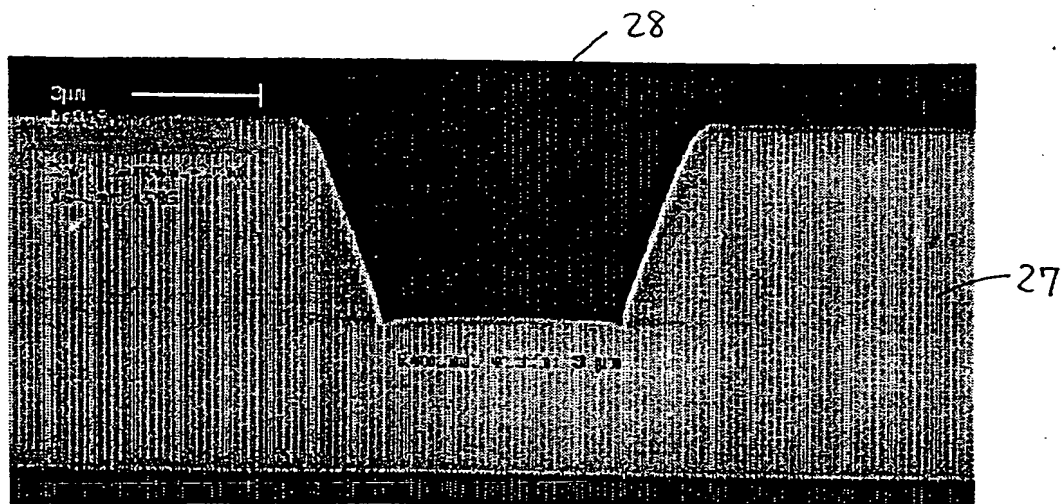


Fig. 21

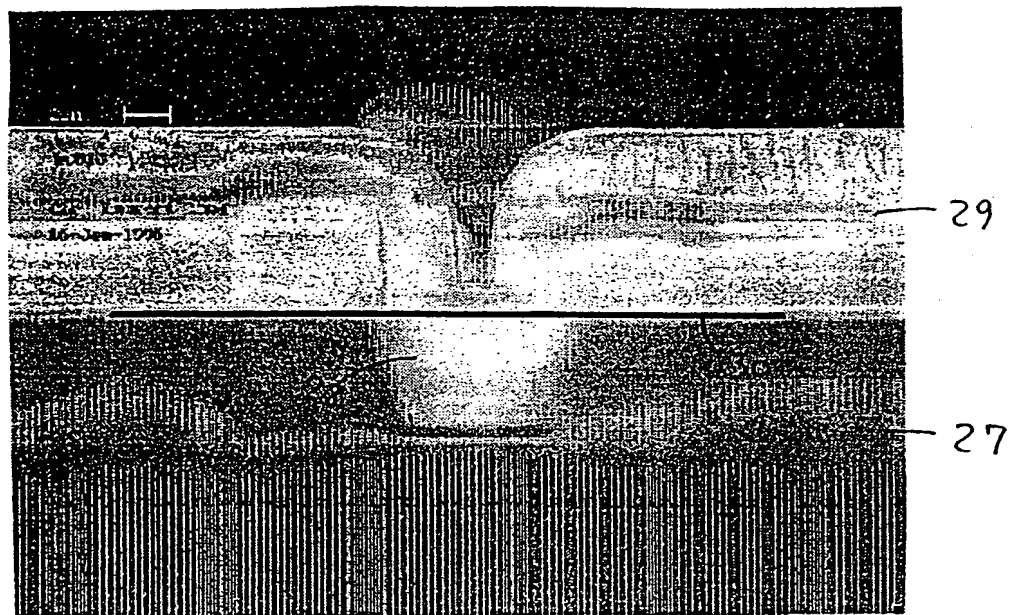


Fig. 22

INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 96/00247

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G02B 6/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4902086 A (CHARLES H HENRY ET AL), 20 February 1990 (20.02.90) -- -----	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 Sept 1996

Date of mailing of the international search report

07 -10- 1996

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INTERNATIONAL SEARCH REPORT

Information on patent family members

05/09/96

International application No.

PCT/DK 96/00247

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4902086	20/02/90	CA-A- 1323783	02/11/93
		DE-D, T- 68908583	31/03/94
		EP-A, B- 0331335	06/09/89
		SE-T3- 0331335	
		JP-A- 1267509	25/10/89
		SG-A- 25894	17/03/95
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